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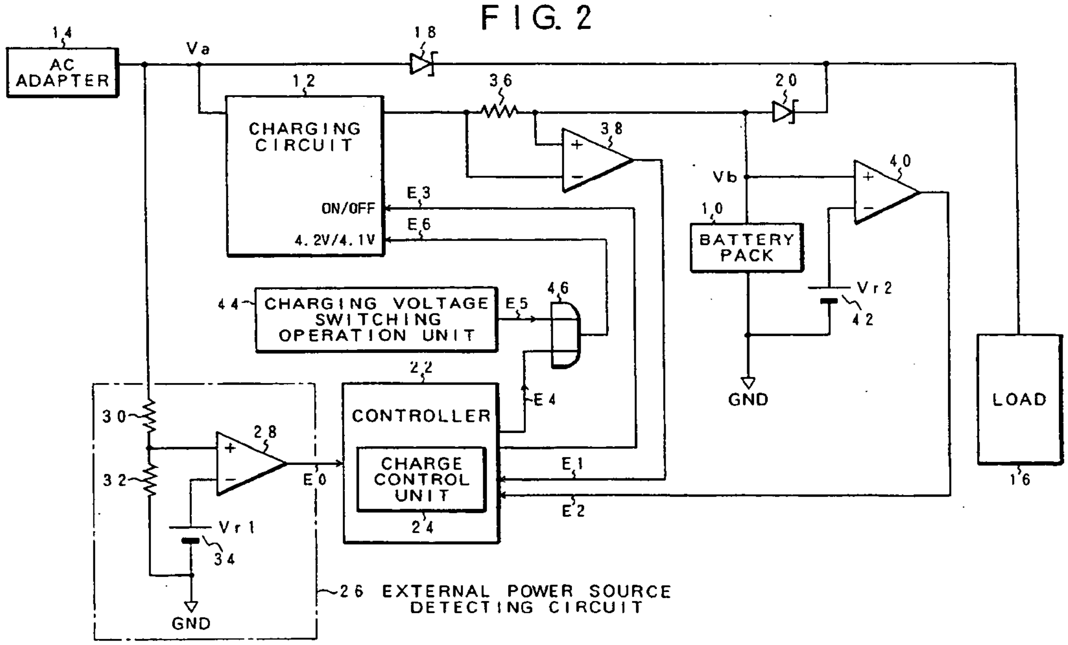
(54) Portable electronic apparatus, charging apparatus and method thereof

(57) When starting charging of an internal battery (10) as a result of connection of an external power source by an AC adapter (14), a charging control unit (24) sets a first charging voltage at which the charging capacity of the internal battery is maximized. When starting the charging from recognition of reduced capacity of the internal battery (10) due to its self-discharge in desk-top use where the AC adapter (14) is in connection at all times, the charging control unit (24) sets a second charging voltage lower than the first charging voltage to prevent the battery from degrading.

FIG. 2



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Description

[0001] The present invention relates generally to a portable electronic apparatus which, upon connection with an external power source by way of, e.g., an AC adapter, supplies electric power from the external power source to a load and charges an internal battery, and to a charging apparatus and method for the portable electronic apparatus. More particularly, the invention relates to a portable information processing apparatus for preventing degradation of the battery during use with the external power source connected, as well as to a charging apparatus and method for the information processing apparatus.

[0002] With recent progress toward miniaturization of elements, high integration of LSIs and high performances of CPUs with enriched communication facilities such as cellular phones, personal computer communications and the Internet, markets for portable equipment such as notebook-sized personal computers, hand-held terminals, mobile computers, etc., are expanding. Use of a lithium ion battery (L+ battery) as the battery for such hand-held equipment is rapidly spreading of late. The lithium ion battery has a weight energy density about three times and a volume energy density about twice that of the nickel-cadmium hydrogen battery.

[0003] The lithium ion battery is a small-sized and lightweight high-capacity battery and is used for various portable equipment. The lithium ion battery includes, as its basic unit, battery cells generating a nominal voltage of 3.6 volts and has a tubular or rectangular package for housing a corresponding number of cells to the power-supply voltage required by the equipment. For example, two cells and three cells correspond to 7.2 volts and 10.8 volts, respectively.

[0004] The mode of charging a lithium ion battery loaded in portable equipment such as a notebook-sized personal computer needs to be constant-voltage constant-current charge. In such battery charge, the quantity of charge is determined depending on the charging voltage, charging current and charging time. In the case of portable equipment such as a notebook-sized personal computer, the useful operating time becomes longer according to the quantity of charge of the lithium ion battery, i.e., the capacity upon the full charge is larger. For this reason, the charging is made at as high a voltage as possible within a permissible range so as to secure a larger capacity upon the full charge. It is further necessary to set as a final discharge voltage a minimum voltage value ensuring a stable operation of the equipment, but the apparatus operation time may vary depending on the level of setting the final discharge voltage.

[0005] On the other hand, the lithium ion battery has degradation properties such that its capacity lowers in the same manner as the case of the charge and discharge merely by being left to stand in a high-temperature environment in a charged state. The degree of degradation depends on the temperature at which it stands and on the charging voltage, so that the degradation accelerates with temperature. For example, a notebook PC may be used on a desk with the AC adapter connected at all times without ever being used on the move (hand-held use), so that the notebook-sized personal computer is constantly powered from the AC adapter and is not at all powered by the internal battery. However, taking AC supply abnormalities such as a short break, instantaneous stop or service interruption into consideration, then irrespective of the constant supply of power for the notebook-sized personal computer from the AC adapter, it is not preferable that the battery charge capacity is null. Furthermore, in the event that hand-held use is suddenly desired after long desk-top use, the empty battery will not permit the hand-held use till the termination of the battery charging. For this reason, the charging capacity of the internal battery must be kept in the full charged state in proximity to 100% even in the cases where the notebook-sized personal computer is nearly always used on a desk with the AC adapter connected.

[0006] Normally, during operation with the AC adapter connected, there is no supply of power from the internal battery to the apparatus, so that once the internal battery is charged, the charging capacity will remain near-fully charged close to 100%, with no need for recharging. However, without limitation to the lithium ion battery, the secondary battery may suffer a gradually decreasing charging capacity due to internal leakage even in its full-charged state. This is called self-discharge. Thus, even in the event that the apparatus such as the notebook-sized personal computer is operated with the AC adapter connected, it is necessary to perform recharging to compensate for the reduction of the charging capacity attributable to the self-discharge of the internal battery.

[0007] In the case of a Nicad battery or NiMH battery, a common method is trickle charging in which a current equal to the self-discharge continues to be charged at all times. Alternatively, due to the risk that the battery may be damaged by continuous trickle charging, the charge remaining in the battery is monitored so that charging is effected when the remainder has reduced to a certain degree, to thereby compensate the quantity of self-discharge.

[0008] For this reason, desk-top use of the notebook-sized personal computer with the AC adapter connected at all times allows the power to be supplied from the AC adapter to the load, so that although there is no discharge from the lithium ion battery, the lithium ion battery is always kept in the full charged state, which may cause any degradation without charge and discharge for the load. Such a problem occurs similarly irrespective of its significance in not only the lithium ion battery but also in other types of battery such as lithium polymer.

[0009] Raising the charging voltage of the lithium ion secondary battery will increase the charging capacity and elongate the battery-based operating time of the

notebook-sized personal computer in hand-held use; however, the raised charging voltage may cause the same degradation as the case of charge and discharge of the battery even in the case where the battery is not discharged in the AC adapter-based operation. A simple approach to solution of degradation of the battery in the high-temperature environment is to lower the charging voltage. The lowered battery charging voltage can prevent the degradation of the battery in the high-temperature environment, but may shorten the battery-based operating time of the notebook-sized personal computer due to the reduced quantity of battery charge.

[0010] According to the present invention there are provided a portable electronic apparatus, a charging apparatus and a charging method wherein when the apparatus is used away from an AC supply ("hand-held use"), the charging voltage of the battery is raised to increase the charging capacity so that the battery operating time is maximized, whereas when the apparatus is used with an AC supply ("desk-top use") with the AC adapter connected at all times, the charging voltage of the battery is lowered to thereby prevent any degradation of the battery in a high-temperature environment.

[0011] Identification of whether the apparatus such as the personal computer is in hand-held use or desk-top use can be made by identifying a trigger phenomenon upon the start of the charging of the battery incorporated in the apparatus. When the apparatus such as the personal computer is in desk-top use, the AC adapter remains connected at all times. In this case, the charging is mainly directed to replenishment of the self-discharge of the internal battery. On the other hand, hand-held use usually necessitates battery-based apparatus operation. For this reason, charging of the internal battery is performed when the AC adapter is mounted on the apparatus or when the internal battery is loaded in the apparatus with the AC adapter being connected to the apparatus. In this manner, the mode of operation of the apparatus can be recognized in a corresponding manner to the trigger phenomenon to start the charge of the internal battery. Thus, the present invention provides a portable electronic apparatus, a charging apparatus and a charging method which realize both the prevention of degradation of the battery in desk-top use with the AC adapter connected at all times and the securement of the battery charging capacity in hand-held use.

[0012] According to first and second aspects of the present invention there are provided a portable electronic apparatus and a charging apparatus which, when an external power source is unconnected for example, supply electric power from an internal battery to a load and which, upon connection with the external power source, supply electric power from the external power source to the load and charge the internal battery, the apparatuses each comprising a charging circuit capable of charging the battery by setting different charging voltages; and a charging control unit which variably sets the charging voltage of the internal battery in response to a trigger phenomenon (such as connection of the AC adapter) to start charging of the internal battery.

[0013] Thus, in the present invention, the charging voltage is raised to effect charging as much as possible during initial charge upon the detection of connection with the AC adapter and upon the detection of loading of the battery, whereas the charging voltage is lowered during supplementary charge for supplementing the reduction attributable to the self-discharge, to thereby suppress the occurrence of the charge/discharge cycle arising from the self-discharge of the lithium ion battery, and consequently prevent the degradation of the battery and elongate the service life thereof.

[0014] In this event, correspondingly to the trigger phenomenon to start charging of the internal battery, the charging control unit sets either a first charging voltage at which the charging capacity of the internal battery is maximized or a second charging voltage which is lower than the first charging voltage. When starting charging of the internal battery as a result of connection with the external power source, the charging control unit sets the first charging voltage at which the charging capacity of the internal battery is maximized, and when starting charging as a result of recognition of a reduction in the capacity of the internal battery due to its self-discharge, the charging control unit sets the second charging voltage which is lower than the first charging voltage.

[0015] With the external power source connected, when starting charging of the battery as a result of installing the internal battery in the apparatus, the charging control unit sets the first charging voltage at which the charging capacity of the internal voltage is maximized, and with the external power source connected, when starting charging as a result of recognition of a reduction in the capacity of the internal battery due to its self-discharge, the charging control unit sets the second charging voltage which is lower than the first charging voltage.

[0016] The apparatuses may each further comprise a setting change unit which changes set voltages as charging voltages to be set for the charging circuit to any voltages, the set voltages being defined for each trigger phenomenon to start charging of the internal battery. As to the lithium ion battery, the setting change unit sets for the charging circuit the first charging voltage of 4.2V per cell and the second charging voltage of 4.1V per cell for example.

[0017] The apparatuses may each further comprise a switching operation unit by means of which, for the charging circuit, the user switches the charging voltage to either the first charging voltage or the second charging voltage. This enables the selection of the charging voltage to be made by the judgment of the user. For instance, upon the hand-held use with the AC adapter removed, the user may change the setting of the charging voltage to a higher voltage previous to the removal of the AC adapter, whereby the user can shift to the hand-held use after maximizing the charge.

[0018] According to a third aspect of the present invention there is provided a method of charging equipment which, when an external power source is unconnected, supplies electric power from an internal battery to a load and which, upon connection with the external power source, supplies electric power from the external power source to the load and charges the internal battery, the method comprising the step of changing the charging voltage of said internal battery in response to trigger phenomenon which triggers charging of the internal battery, to charge said internal battery.

[0019] More specifically, the method may further comprise the step of, in response to a trigger phenomenon to start charging the internal battery, setting either a first charging voltage at which the charging capacity of the internal battery is maximized or a second charging voltage which is lower than the first charging voltage, to charge the internal battery. The details of this charging method are substantially the same as the case of the apparatus configuration.

[0020] Reference will now be made, by way of example only, to the accompanying drawings in which:-

Fig. 1 is an explanatory diagram of a notebook-sized personal computer employing the present invention;
Fig. 2 is a circuit block diagram of an embodiment of the present invention incorporated in the notebook-sized personal computer of Fig. 1;
Fig. 3 is a circuit block diagram of a charging circuit of Fig. 2;
Fig. 4 is a circuit block diagram of a control IC of Fig. 3;
Figs. 5A to 5C are time charts of the charging control of Fig. 2; and
Figs. 6A and 6B are flowcharts of the charging control of Fig. 2.

[0021] Fig. 1 depicts a notebook-sized personal computer acting as a hand-held information processor provided with a charging apparatus in accordance with the present invention. The notebook-sized personal computer is designated generally at 100 and comprises a body 102 and a cover 104 which has on its inner side a liquid crystal color display 106. The body 102 includes a keyboard 108, a flat point (touch panel) 110 positioned closer to the operator than the keyboard 108, the flat point 110 being used to operate a mouse pointer on the liquid crystal display 106, and a left click button 112 and a right click button 114 which are positioned closer to the operator than the flat point 110, the right 112 and left 114 click buttons corresponding to left and right buttons of the mouse, respectively.

[0022] Fig. 2 is a block diagram of the charging apparatus incorporated in the notebook-sized personal computer. The notebook-sized personal computer serving as the hand-held information processor comprises a battery pack 10 using a lithium ion battery cell as an internal battery, with a charging circuit 12 associated with the battery pack 10. A supply of external power is effected by a connection of an AC adapter 14. When a plug of the AC adapter 14 is connected to an AC power source, a predetermined DC voltage Va is output from the AC adapter 14. A power supply line from the AC adapter 14 is connected via a diode 18 to a load 16 of the computer. An output line from the AC adapter 14 branches to the charging circuit 12, with output from the charging circuit 12 being connected via a current sense resistor 36 to the positive side of the battery pack 10 and further via a diode 20 to the load 16 through the power supply line from the AC adapter 14.

[0023] The battery pack 10 incorporates e.g., a single-cell lithium ion battery which supplies a nominal battery voltage Vb of 3.6V per cell to the load. The charging voltage maximizing the capacity at the full charge per cell of the lithium ion battery is set to e.g., 4.2V. Although the battery pack 10 incorporates a single lithium cell having a nominal battery voltage of 3.6V and a charging voltage of 4.2V by way of example, the number of cells used may be increased if necessary. In such a case, the nominal battery voltage and the charging voltage increase in proportion to the number of cells. With two cells for example, the nominal battery voltage and the charging battery voltage result in 7.2V and 8.4V, respectively. With three cells, the nominal battery voltage and the charging battery voltage result in 10.8V and 12.6V, respectively.

[0024] When the battery pack 10 is in full charge, the output voltage Va from the AC adapter 14 is higher than the battery voltage Vb. For this reason, in cases where external power is supplied as a result of connection of the AC adapter 14, the diode 18 conducts under forward bias so that electric power is supplied from the AC adapter 14 to the load 16. On the contrary, for the battery pack 10, the diode 20 remains off under reverse bias by the adapter output voltage Va higher than the battery voltage Vb, so that the battery pack 10 is not at all charged by the output voltage Va of the AC adapter 14.

[0025] The charging circuit 12 is under charging control for the battery pack 10 by a charging control unit 24 included in a controller 22. The controller 22 can be a one-chip MPU for example and the function of the charging control unit 24 is implemented by its control program thereof. The controller 22 is associated with an external power source detection circuit 26. The external power source detection circuit 26 includes a comparator 28, resistors 30 and 32, and a reference voltage source 34. The output voltage Va of the AC adapter 14 is voltage-divided by the resistors 30 and 32 to be applied to the positive input terminal. The comparator 28 compares it with a reference voltage Vr1 at the negative input terminal 34. If the output voltage Va is higher than the reference voltage Vr1, then the comparator 28 generates a high output so that the charging control unit 24 of the controller 22 can recognize the state of connection of the AC adapter 14. The charging control unit 24 of the

controller 22 allows a comparator 40 to compare the battery voltage Vb of the battery pack 10 with a reference voltage Vr2 of a reference voltage source 42 and outputs a charge-on signal E3 to the charging circuit 12 in response to a low output from the comparator 40 when the battery voltage Vr2 becomes less than the reference voltage Vr2, to thereby start the charging.

[0026] A constant-voltage constant-current charging is effected for the charge of the battery pack 10 by the charging circuit 12. During this constant-voltage constant-current charging, a comparator 38 detects a voltage proportional to the charging current through the current sense resistor 36 inserted in the output line from the charging circuit 12 and feeds a current sense signal E1 to the controller 22. When the charging current by the current sense signal E1 becomes not more than a predetermined current, e.g., 50 mA, the controller 12 judges that the charging of the battery pack 10 has reached 100% and halts the charge-on signal E3 to turn off the charging operation of the charging circuit 12.

[0027] Furthermore, in the present invention, when starting the charging in response to the detection of mounting of the AC adapter 14 by the external power source detection circuit 26 where the external power is supplied by the connection of the AC adapter 14, the charging control unit 24 included in the controller 22 judges that hand-held use is required and sets for the charging circuit 12 a first charging voltage Vc1 whose maximum conforms to the charging capacity of the battery pack 10, based on a charging voltage set signal E4, for charging. 4.2V/cell is defined as the first charging voltage Vc1 whose maximum conforms to the capacity in charge use.

[0028] In the event that the external power source already connected by way of the AC adapter 14, and charging of the battery is started as a result of mounting of the battery pack 10, the charging control unit 24 judges that hand-held use is required similar to the detection of connection of the AC adapter and sets the first charging voltage Vc1 = 4.2V/cell where the charging capacity of the internal battery becomes as large as possible, to effect the charging.

[0029] In contrast with this, when starting the charging as a result of recognition of a decreased capacity attributable to the self-discharge of the battery pack 10 in the constantly-connected state of the AC adapter 14, the charging control unit 24 judges the desk-top use and switchingly sets the second charging voltage Vc2 = 4.1V/cell lower than the first charging voltage Vc1 = 4.2V/cell in response to a charging voltage set signal E4, to thereby effect the charging by a lower charging voltage than the charging upon the detection of mounting of the AC adapter or upon the detection of mounting of the battery pack. This second charging voltage Vc2 = 4.1V/cell is a voltage lower by 0.1V/cell than the first charging voltage Vc1 = 4.2V/cell and serves to prevent degradation of the battery pack 10 and elongate its service life under a high-temperature environment by lowering the charging voltage.

[0030] The start of charging by the charging control unit 24 of the controller 22 is effected in response to a voltage sense signal E2 from the comparator 40. The comparator 40 compares the voltage of the battery pack 10 with the reference voltage Vr2, e.g., Vr2 = 2.8 volts so that the charging is started by a low output from the comparator 40 when the battery voltage Vb sinks to the reference voltage Vr2 or below as a result of the discharge of the battery pack 10.

[0031] The embodiment of Fig. 2 is further provided with a charging voltage switching operation unit 44 for externally compulsorily switching the charging voltage of the charging circuit 12 in response to a setting operation by the user. Through operation of, e.g., a button disposed on the hand-held apparatus, the charging voltage switching operation unit 44 provides as its output a charging voltage switching signal E5 which in turn is imparted as a charging voltage switching signal E6 via an OR circuit 46 to the charging circuit 12, whereby in this embodiment switching setting can be effected of either the first charging voltage Vc1 = 4.2V/cell or the second charging voltage Vc2 = 4.1V/cell.

[0032] In the event that the user initially makes desktop use with the AC adapter 14 connected at all times and thereafter shifts to hand-held use for some reason, the user presses the button to make the charging voltage switching operation unit 44 compulsorily switch the charging voltage of the charging circuit 12 to the higher first charging voltage Vc1 = 4.2V/cell, and thereby charge the battery pack 10 so that the charging capacity thereof becomes as high a level as possible. In addition to the operation of a button disposed on the hand-held equipment, the switching by the charging voltage switching operation unit 44 may be effected through an instruction of the load 16 side to the software in the controller 22, more specifically, through a software instruction by, e.g., a mouse click using the window on the screen.

[0033] Fig. 3 depicts an embodiment of the charging circuit 12 of Fig. 2. The charging circuit 12 is provided with a switching regulator which comprises an FET 48 acting as a switching element, a control IC 50, a rectifying Zener diode 52, an inductance 54 and a smoothing capacitor 56. The switching regulator included in the charging circuit 12 provides a step-down chopper. The control IC 50 receives the charge-on signal E3 and the charging voltage setting signal E6 from the controller 22 of Fig. 2. The control IC 50 further receives a voltage sense signal E7 and an output voltage sense signal E8 through signal lines extending from opposed ends of a current sense resistor 58 inserted in the output line of the switching regulator.

[0034] The control IC 50 has a circuit configuration of Fig. 4. The control IC 50 comprises a PWM comparator 60. The PWM comparator 60 is associated with operational amplifiers 62 and 64 for constant-current control. The operational amplifier 62 receives at its positive input

the current sense signal E7 from the positive side of the current sense resistor 58 of Fig. 3 and receives at its negative input the output voltage sense signal E8 from the output line. The operational amplifier 62 outputs a current sense signal E9 as a difference between the two signals E7 and E8. The current sense signal E9 from the operational amplifier 62 is fed to a negative input of the operational amplifier 64 whose positive input receives the charge-on signal E3 from the controller 22 of Fig. 2. This charge-on signal E3 serves actually as a charging current setting signal for setting a target output current for the comparator 60. For this reason, the operational amplifier 64 outputs to the PWM comparator 60 a constant-current control signal E10 which depends on an error between the current sense signal E9 output from the operational amplifier 62 and the charging current setting signal E3 from the controller 22.

[0035] The PWM comparator 60 compares a triangular wave signal from a triangular wave oscillator 78 with the reference voltage to output a pulsed signal having a pulse width which depends on the reference voltage level, so that the reference voltage level is varied by the constant-current control signal E10 from the operational amplifier 64. For this reason, via a driver 80 the PWM comparator 60 provides a constant-current control by which the switching cycle of the FET 48 is controlled so as to allow the charging current to conform to the charging set current.

[0036] The PWM comparator 60 is further associated with an operational amplifier 66 for constant-voltage control. A negative input of the operational amplifier 66 receives the output voltage sense signal E8 which has been voltage divided by resistors 68 and 70. A positive input of the operational amplifier 66 is connected to a reference voltage source 74 or 76 which is selected by a switching circuit 72. In this case, the reference voltage source 74 generates the first charging voltage Vc1 = 4.2V/cell and the reference voltage source 76 generates the second charging voltage Vc2 = 4.1V/cell, which are switched by the switching circuit 62 that receives the charging voltage switching signal E6 from the controller 22 of Fig. 2. The reference voltage sources 74 and 76 act as variable voltage sources and provide a setting change unit allowing a change of setting of the charging voltage. The comparator 66 outputs to the PWM comparator 60 a constant-voltage control signal E11 in conformity with on an error between either the first charging voltage Vc1 or the second charging voltage Vc2 switched by the switching circuit 72 and the output voltage sense signal which has been voltage divided by the resistors 68 and 70. The comparator 66 then varies the reference voltage level for the triangular wave signal depending on the constant-voltage control signal E11. Via the driver 80, the comparator 66 thus controls the on-time in the switching control of the FET 48 of Fig. 3 so as to keep the output voltage unvarying.

[0037] Figs. 5A to 5C are time charts of the charging control effected upon the connection of the AC adapter 14 in the embodiment of Fig. 2. The AC adapter 14 is unconnected till the time t1. For this reason, an AC adapter detection signal E0 of Fig. 5A is low, allowing the battery pack 10 to supply a power to the load 16. This discharge lowers the battery voltage Vb of Fig. 5C with the lapse of time. Assume that the AC adapter 14 is connected to perform the supply of external power at the time t1 after the battery voltage Vb has dropped below a charging start voltage Vs which is determined by the reference voltage Vr of the reference voltage source 42 of the comparator 40 as a result of supply of power from the battery pack 10 to the load 16. The output voltage Va by the connection of the AC adapter 14 at the time t1 allows the AC adapter detection signal E0 which is an output of the comparator 28 of the external power source detection circuit 26 to go high so that the charging control unit 24 of the controller 22 can recognize the connection of the AC adapter 14. Since the battery voltage Vb at that time has already dropped below the reference voltage Vr2 corresponding to the charge start signal Vs with a low voltage sense signal E2 from the comparator 40, the charging control unit 24 recognizes the charging based on the detection of mounting of the AC adapter 14 and instructs the charging circuit 12 to set the first charging voltage Vc1 = 4.2V/cell by use of the charging voltage setting signal E4.

[0038] The charging control unit 24 further provides a charging on/off signal E3 of Fig. 5B as its output to the charging circuit 12 to thereby start the charging. Thus, from the time t1, the charging circuit 12 starts the constant-current constant-voltage charge for the battery pack 10 with the result that the battery voltage Vb increases toward the charging voltage Vc1 = 4.2V/cell. Then, when the charging control unit 24 detects that the charging current has decreased to a predetermined current, e.g., 50mA from the current sense signal E1 based on the detection voltage at the current sense resistor 36, the charging control unit 24 judges completion of 100% charge to halt the charging of the charging circuit 12 at the time t2. The AC adapter 14 is in connection after the time t2 and hence the load 16 accepts the supply of power from the AC adapter 14, whereupon the supply of power from the battery pack 10 to the load is not effected and the battery pack 10 has a gradually lowering battery voltage Vb attributable to the self-discharge.

[0039] When the battery voltage Vb has dropped below the charging start voltage Vs at the time t3 as a result of lowering of the battery voltage Vb by the self-discharge, the voltage sense signal E2 from the comparator 40 goes low, allowing the charging control unit 24 of the controller 22 to effect the charging by the charging circuit 12. Since the charging is not based on the detection of mounting of the AC adapter 14 in this case, the charging control unit 24 recognizes that the capacity has decreased by its self-discharge and sets for the charging circuit 14 the second charging voltage Vc2 of 4.1V/cell lower than the first cycle in response to the charging voltage setting signal E4, to start the constant-current

constant-voltage charging. The charging is terminated at the time t4 when the charging current has decreased to a normal current.

[0040] After the time t4, as long as the AC adapter 14 is in connection by its desk-top use, the charging by the setting of the second charging voltage Vc2 = 4.1V/cell is iterated (repeated) for the charge loss attributable to the self-discharge. In this manner, with respect to the charging for the reduction of the capacity by the self-discharge, the charging by the setting of the lower charging voltage is iterated to suppress the degradation of the battery. On the other hand, in its hand-held use, the charging by the detection of mounting of the AC adapter 14 is frequency iterated. Thus, in this hand-held use, the setting of the first charging voltage Vc1 = 4.2V/cell enables the charging to be made so that the capacity of the battery pack 10 is maximized.

[0041] Figs. 6A and 6B are flowcharts of the charging control effected by the charging control unit 24 included in the controller 22 of Fig. 2. The charging control unit 24 makes a check in step S1 to see if the charging is to be made or not by the detection of mounting of the battery pack 10. If the battery pack 10 has already been mounted, then the procedure goes to step S2 where it is checked whether the charging is to be made or not by the detection of the AC adapter.

[0042] If the charging by the detection of mounting of the AC adapter is judged in step S2, then it is judged that the apparatus such as the notebook-sized personal computer is in hand-held use, allowing the procedure to go to step S4 where the charging voltage is set to the first charging voltage Vc1 = 4.2/cell.

[0043] If the detection of mounting of the battery cell 10 is discriminated in step S1, then it is discriminated that the apparatus is in connected state by the AC adapter 14 in step S3 to judge the hand-held use. Similarly, the procedure goes to step S4 where the first charging voltage Vc1 = 4.2V/cell is set as the charging voltage.

[0044] On the contrary, if the charging by the detection of mounting of the AC adapter is not discriminated in step S2, then it is judged that the charging has been effected due to the reduction of capacity by the self-discharge of the battery pack 10 in desk-top use, allowing the procedure to go to step S5 to set the second charging voltage Vc2 = 4.1V/cell.

[0045] After the completion of the setting of the charging voltage in step S4 or step S5, the charging current is set in step S6 and the charging circuit 12 is operated in step S7 to effect the constant-current constant-voltage charging.

[0046] Then, in step S8 the process waits until charging has halted, and in step S9 a check is made of the request to halt the charge. The completion of charge is checked in step S10, and if affirmative, then the procedure goes to step S11 to perform the charge completion processing, after which the charging circuit 12 is stopped in step S13. If a charge halt request occurs during the charge, then the procedure goes from step S9 to step S12 to perform the charge halt processing, after which the charging circuit 12 is stopped in step S13.

[0047] According to the present invention, as set forth hereinabove, the charging voltage is raised to maximize the charging capacity when starting the charge of battery as a result of judgment of the hand-held use of the apparatus from the detection of mounting of the AC adapter or from the detection of mounting of the internal battery with the AC adapter connected, whereas the charging voltage is lowered when starting the charging as a result of recognition of reduced capacity attributable to the self-discharge of the internal battery, whereby it is possible to prevent the degradation of the battery in the high-temperature environment and to elongate the service life.

[0048] Although the above embodiment has been directed to a lithium ion battery by way of example, the present invention is not limited thereto and is equally applicable to, e.g., a lithium polymer battery or any other battery used as a secondary battery in hand-held equipment, wherever it may usefully be employed against the degradation attributable to the discharge by the internal impedance of the battery with the AC adapter connected. In this case, specific values of the first charging voltage Vc1 and of the second charging voltage Vc2 can be ones suited for the performances of the respective batteries.

[0049] The present invention is intended to include any variants without impairing the advantages thereof and is by no means restricted by numerical values indicated in the above embodiment.

[0050] Although the above description refers to "hand-held" equipment, the present invention is not restricted to equipment capable of being held in the hand, but rather it is applicable to any equipment capable of use remote from an AC supply. Likewise, the term "information processing apparatus" has a broad meaning and encompasses, in addition to computing devices, entertainment devices such as video games, digital cameras and DVD players.

Claims

1. A portable electronic apparatus which, when an external power source is unconnected, supplies electric power from an internal battery to a load and which, upon connection with said external power source, supplies electric power from said external power source to said load and charges said internal battery, said apparatus comprising:

    a charging circuit capable of charging said battery by setting different charging voltages; and
    a charging control unit which variably sets the charging voltage of said internal battery in response to a trigger phenomenon to start charging of said internal battery.

2. The apparatus according to claim 1, wherein in response to said trigger phenomenon to start charging of said internal battery, said charging control unit sets either a first charging voltage at which the charging capacity of said internal battery is maximized or a second charging voltage which is lower than said first charging voltage.

3. The apparatus according to claim 2, wherein when starting charging of said internal battery as a result of connection with said external power source, said charging control unit sets said first charging voltage for charging at which the charging capacity of said internal battery is maximized, and wherein when starting charging as a result of recognition of a reduction in the capacity of said internal battery due to its self-discharge, said charging control unit sets said second charging voltage which is lower than said first charging voltage.

4. The apparatus according to claim 2 or 3, wherein with said external power source connected, when starting charging of said battery as a result of mounting of said internal battery on said apparatus, said charging control unit sets said first charging voltage at which the charging capacity of said internal voltage is maximized, and wherein with said external power source connected, when starting charging as a result of recognition of a reduction in the capacity of said internal battery due to its self-discharge. said charging control unit sets said second charging voltage which is lower than said first charging voltage.

5. The apparatus according to any preceding claim, further comprising a setting change unit which changes set voltages as charging voltages to be set for said charging circuit to any voltages, said set voltages being defined for each trigger phenomenon to start charging of said internal battery.

6. The apparatus according to any preceding claim, further comprising a switching operation unit which, for said charging circuit, switches said charging voltage to any of said different charging voltages.

7. A charging apparatus for equipment which, when an external power source is unconnected, supplies electric power from an internal battery to a load and which, upon connection with said external power source, supplies electric power from said external power source to said load and charges said internal battery. said apparatus comprising:

a charging circuit capable of charging said battery by setting different charging voltages; and
a charging control unit which variably sets the charging voltage of said internal battery in response to a trigger phenomenon to start charging of said internal battery.

8. The apparatus according to claim 7, wherein in response to said trigger phenomenon to start charging of said internal battery, said charging control unit sets either a first charging voltage at which the charging capacity of said internal battery is maximized or a second charging voltage which is lower than said first charging voltage.

9. The apparatus according to claim 8, wherein when starting charging of said internal battery as a result of connection with said external power source, said charging control unit sets said first charging voltage for charging at which the charging capacity of said internal battery is maximized, and wherein when starting charging as a result of recognition of a reduction in the capacity of said internal battery due to its self-discharge, said charging control unit sets said second charging voltage which is lower than said first charging voltage.

10. The apparatus according to claim 8 or 9, wherein with said external power source connected, when starting charging of said battery as a result of mounting of said internal battery on said apparatus, said charging control unit sets said first charging voltage at which the charging capacity of said internal voltage is maximized, and wherein with said external power source connected, when starting charging as a result of recognition of a reduction in the capacity of said internal battery due to its self-discharge, said charging control unit sets said second charging voltage which is lower than said first charging voltage.

11. The apparatus according to claim 7, 8, 9, or 10, further comprising a setting change unit which changes set voltages as charging voltages to be set for said charging circuit to any voltages, said set voltages being defined for each trigger phenomenon to start charging of said internal battery.

12. The apparatus according to any of claims 7 to 11, further comprising a switching operation unit which, for said charging circuit, switches said charging voltage to any of said different charging voltages.

13. A method of charging equipment which, when an external power source is unconnected, supplies electric power from an internal battery to a load and which, upon connection with said external power source, supplies electric power from said external power source to said load and charges said internal battery, said method comprising the step of:

in response to a trigger phenomenon to start

the charging of said internal battery, changing the charging voltage of said internal battery to charge said internal battery.

14. The method according to claim 13, further comprising the step of:

in response to the trigger phenomenon to start the charging of said internal battery, setting either a first charging voltage at which the charging capacity of said internal battery is maximized or a second charging voltage which is lower than said first charging voltage, to charge said internal battery.

15. The method according to claim 14, further comprising the step of:

when starting charging of said internal battery as a result of connection with said external power source, setting said first charging voltage for charging at which the charging capacity of said internal battery is maximized, and when starting charging as a result of recognition of a reduction in the capacity of said internal battery due to its self-discharge, setting said second charging voltage for charging which is lower than said first charging voltage.

16. The method according to claim 14 or 15, further comprising the step of:

with said external power source connected, when starting charging of said battery as a result of mounting of said internal battery on said apparatus, setting said first charging voltage at which the charging capacity of said internal voltage is maximized, and with said external power source connected, when starting charging as a result of recognition of a reduction in the capacity of said internal battery due to its self-discharge, setting said second charging voltage which is lower than said first charging voltage.

17. The method according to claim 13, 14, 15, or 16, further comprising the step of:

changing a set voltage to any voltage, said set voltage being defined for each trigger phenomenon to start charging of said internal battery.

18. The method according to any of claims 13 to 17, further comprising the step of:

switching said charging voltage to any of said different charging voltages.

FIG. 1

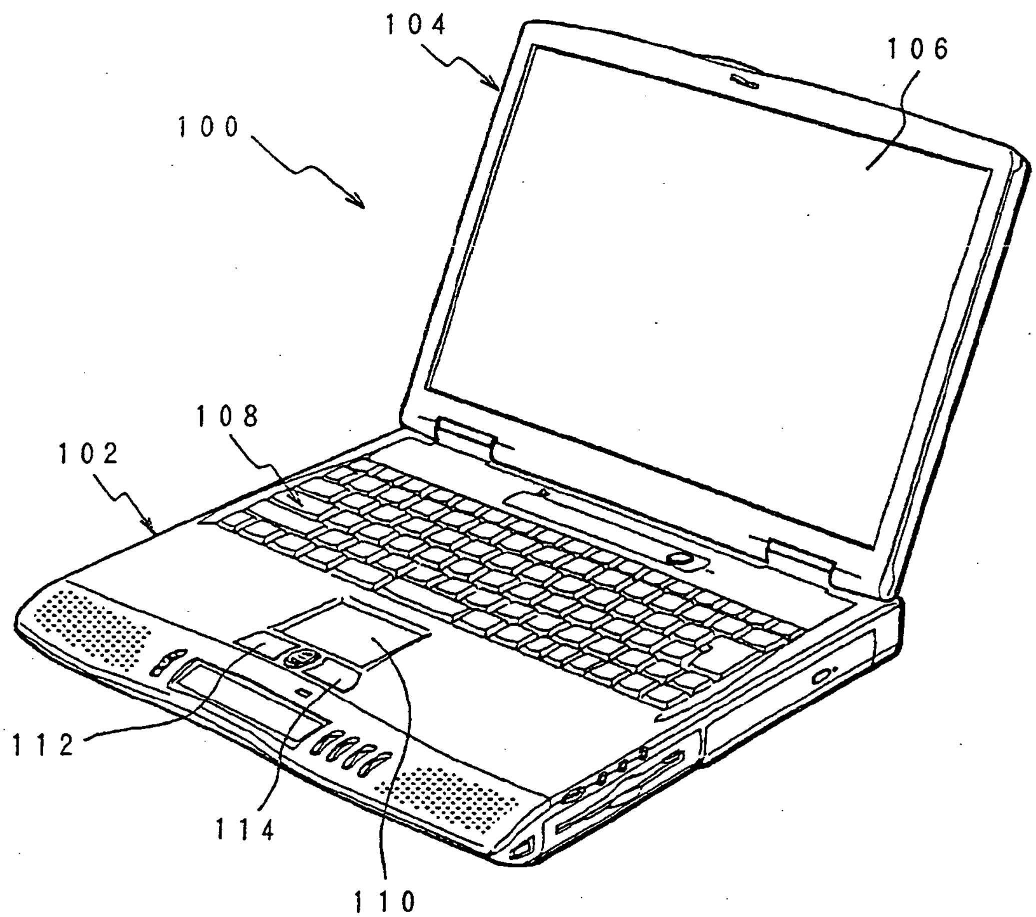


FIG. 2

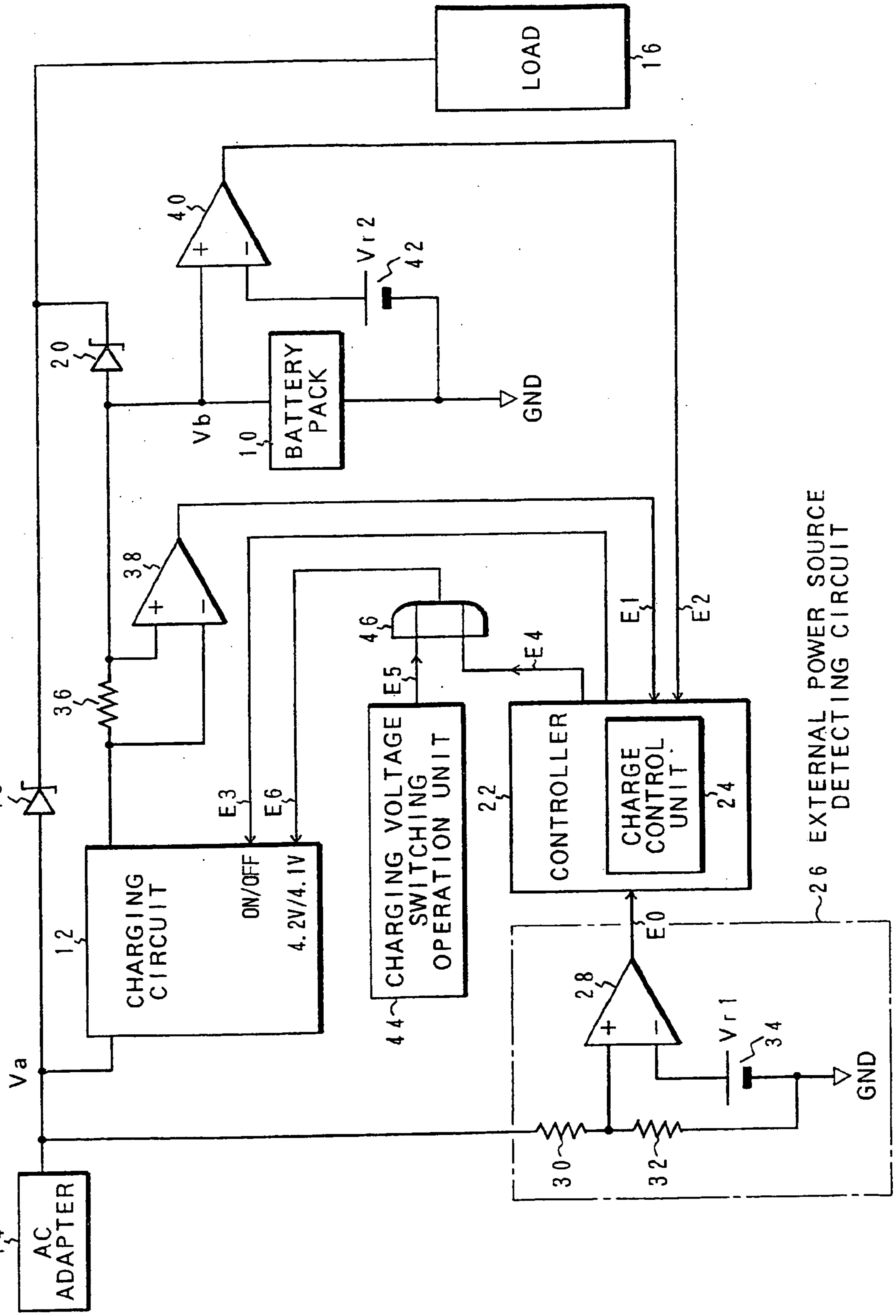

AC ADAPTER
14
Va
18
CHARGING CIRCUIT
12
ON/OFF
4.2V/4.1V
36
38
E3
E6
CHARGING VOLTAGE SWITCHING OPERATION UNIT
44
E5
46
E4
CONTROLLER
22
CHARGE CONTROL UNIT
24
E1
E2
E0
26 EXTERNAL POWER SOURCE DETECTING CIRCUIT
28
Vr1
34
GND
30
32
20
Vb
BATTERY PACK
10
GND
40
Vr2
42
LOAD
16

FIG. 3

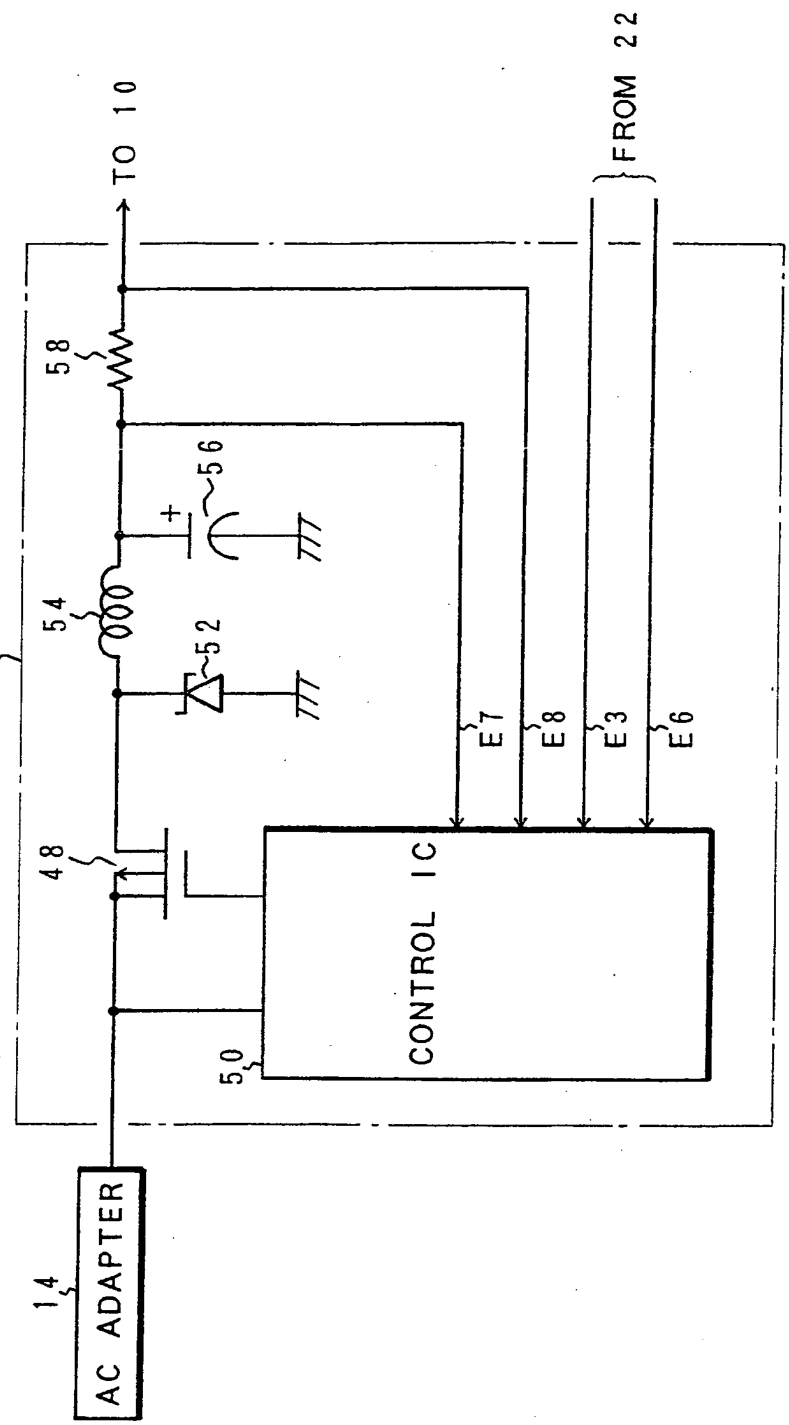
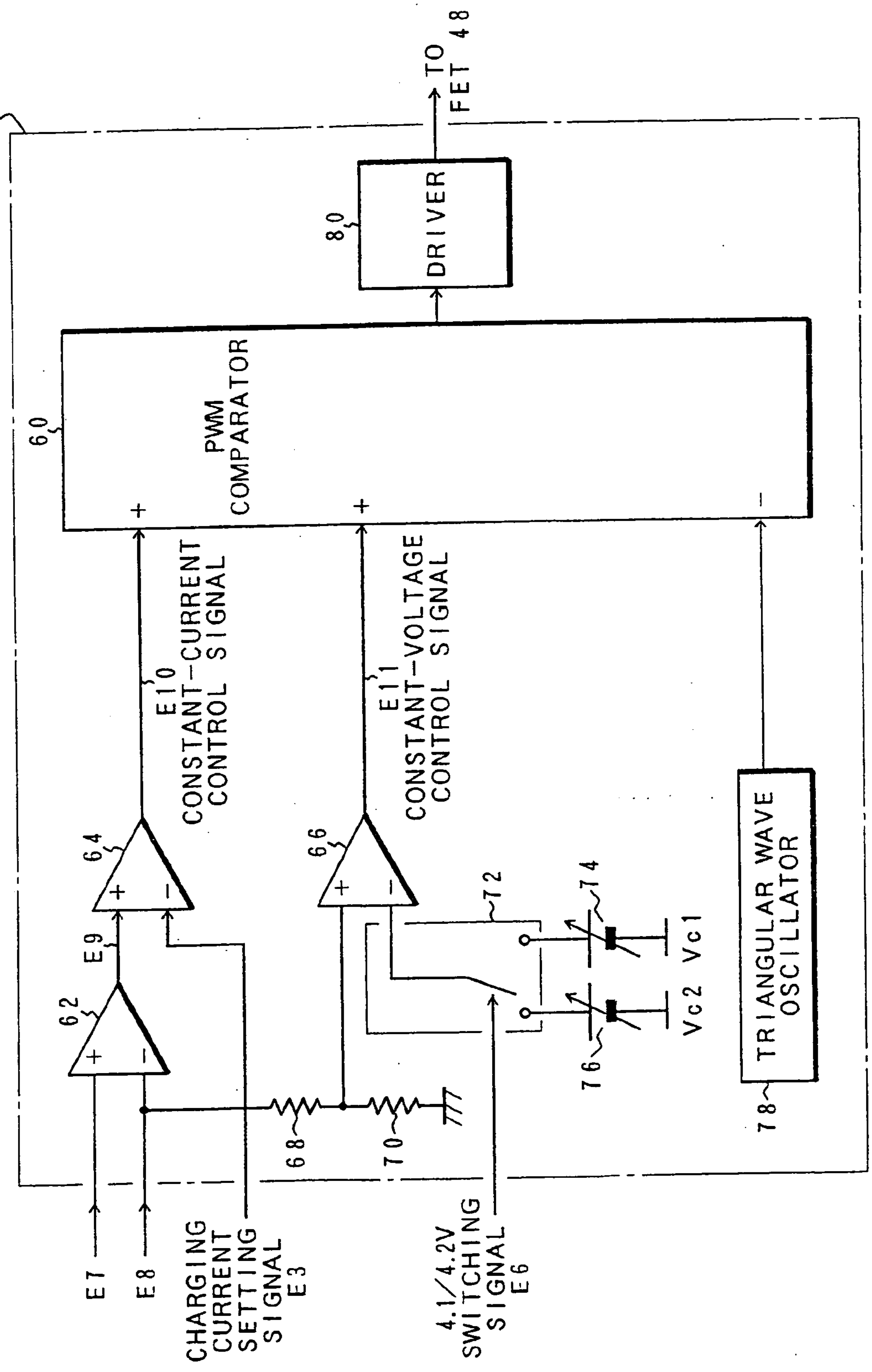

TO 10
FROM 22
12
58
56
54
52
48
50
E7
E8
E3
E6
CONTROL IC
AC ADAPTER
14

FIG. 4


50
TO FET 48
80
DRIVER
60
PWM COMPARATOR
+
+
-
E10
CONSTANT-CURRENT CONTROL SIGNAL
E11
CONSTANT-VOLTAGE CONTROL SIGNAL
64
66
62
E9
72
74
76
Vc1
Vc2
TRIANGULAR WAVE OSCILLATOR
78
68
70
E7
E8
CHARGING CURRENT SETTING SIGNAL E3
4.1/4.2V SWITCHING SIGNAL E6

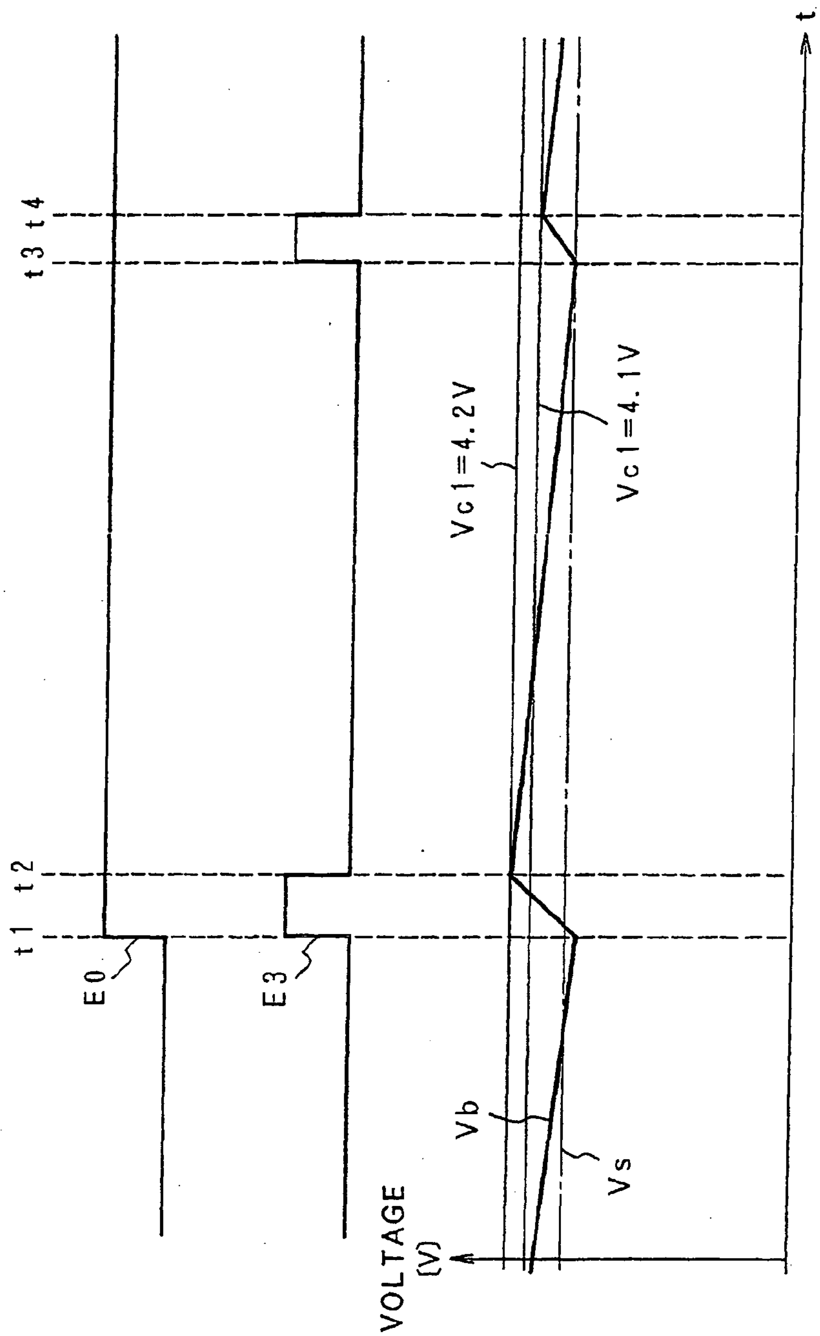


FIG. 5A

FIG. 5B

FIG. 5C

FIG. 6A

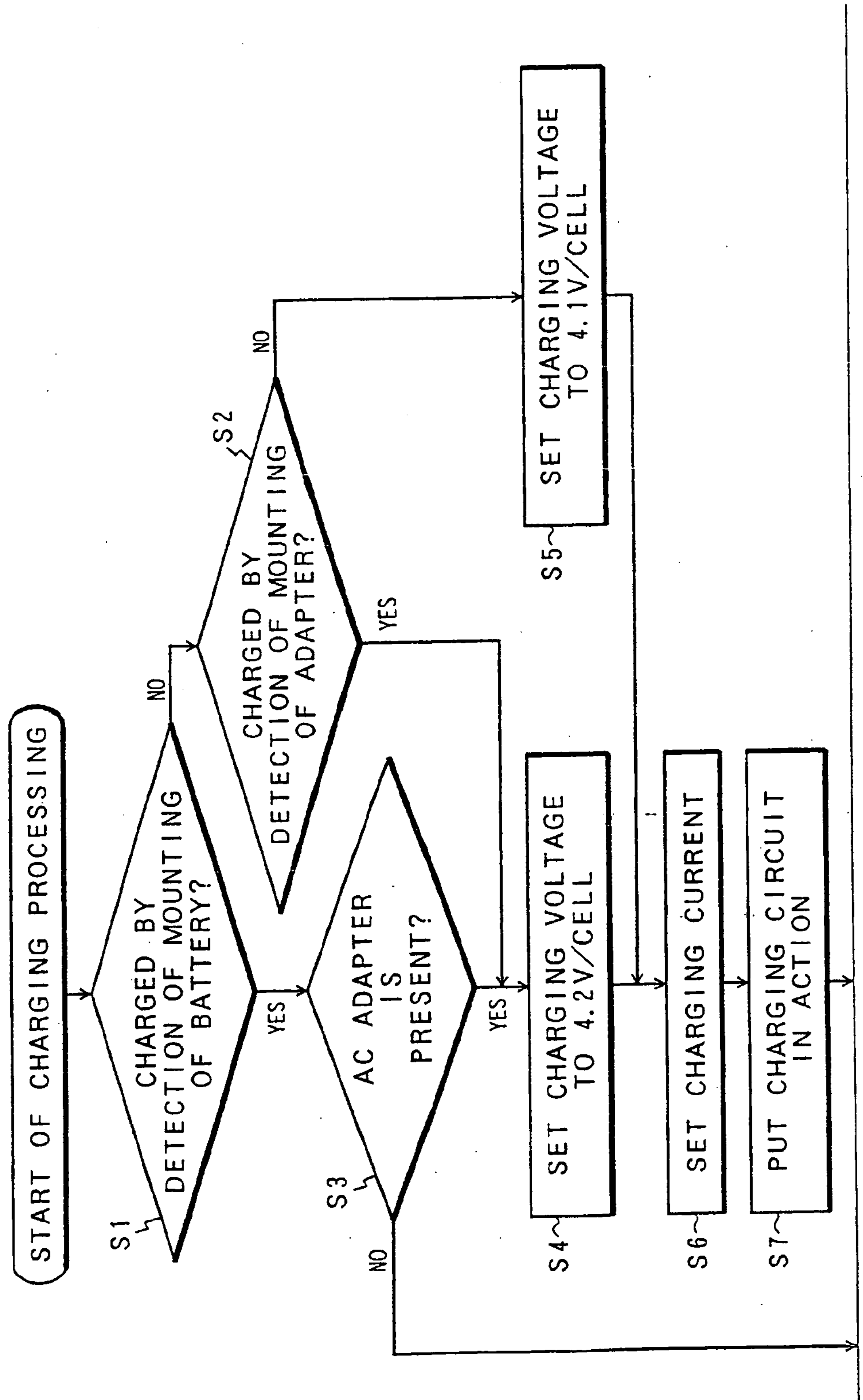
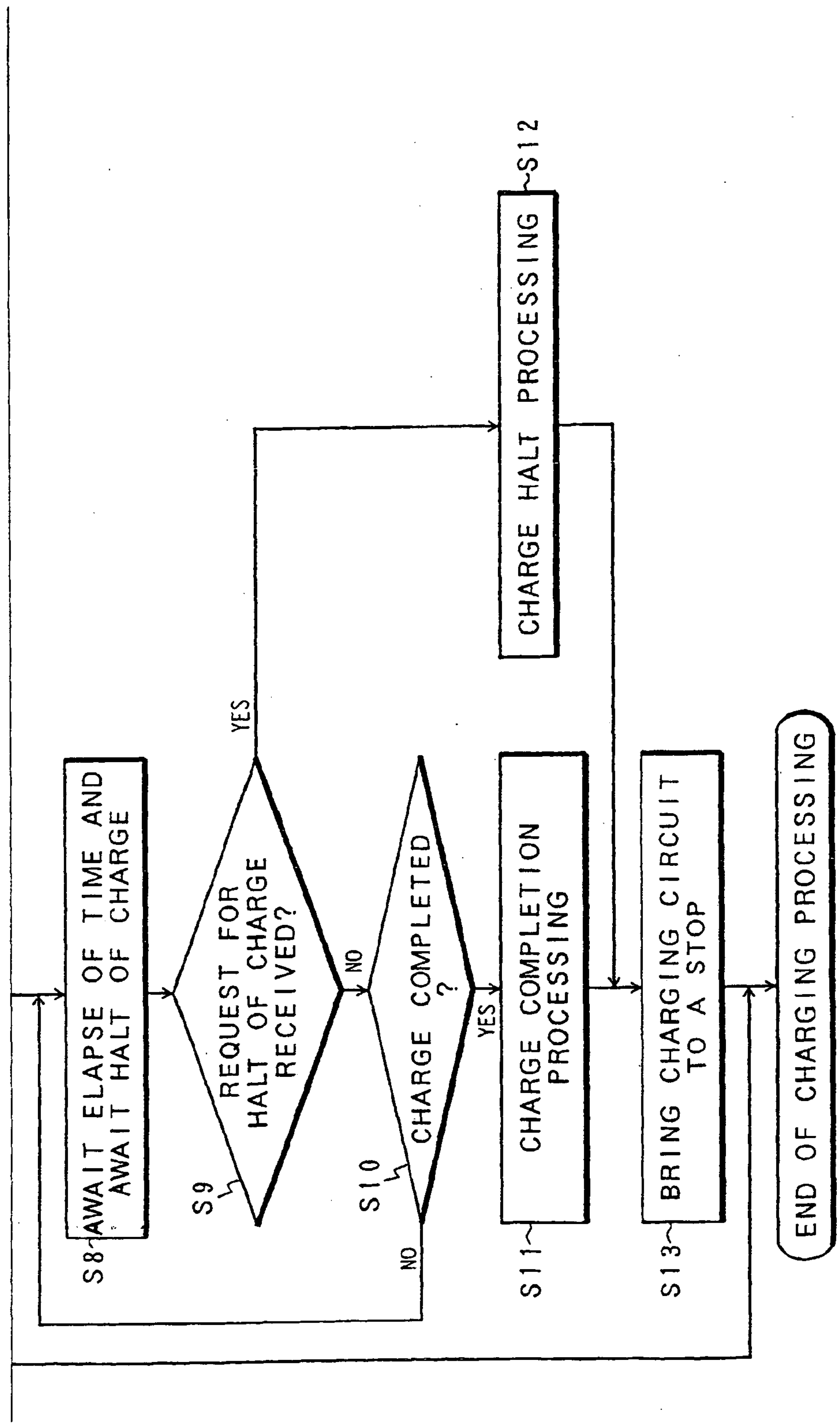

START OF CHARGING PROCESSING
S1
CHARGED BY DETECTION OF MOUNTING OF BATTERY?
YES
NO
S2
CHARGED BY DETECTION OF MOUNTING OF ADAPTER?
YES
NO
S3
AC ADAPTER IS PRESENT?
YES
NO
S4
SET CHARGING VOLTAGE TO 4.2V/CELL
S5
SET CHARGING VOLTAGE TO 4.1V/CELL
S6
SET CHARGING CURRENT
S7
PUT CHARGING CIRCUIT IN ACTION

FIG. 6B


AWAIT ELAPSE OF TIME AND AWAIT HALT OF CHARGE
S8
REQUEST FOR HALT OF CHARGE RECEIVED?
S9
YES
NO
CHARGE COMPLETED ?
S10
YES
NO
CHARGE HALT PROCESSING
S12
CHARGE COMPLETION PROCESSING
S11
BRING CHARGING CIRCUIT TO A STOP
S13
END OF CHARGING PROCESSING

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 30 7115

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X Y	US 5 886 499 A (HALL JOHN C) 23 March 1999 (1999-03-23) * abstract * * column 1, line 6 - column 1, line 17 * * column 1, line 58 - column 2, line 24 * * column 3, line 1 - line 11; figure 2 * * column 3, line 63 - column 4, line 22; claim 1 *	7,8,11, 13,14,17 1,2,5	H02J7/00 H02J7/04
Y A	EP 1 043 824 A (FUJITSU LTD) 11 October 2000 (2000-10-11) * abstract; figures 1,6 * * column 1, line 10 - column 3, line 43 *	1,2,5 3,4,6,7, 13	
A	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 06, 30 April 1998 (1998-04-30) & JP 10 051968 A (NISSAN MOTOR CO LTD), 20 February 1998 (1998-02-20) * abstract *	1,7,13	

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H02J
H01M
G06F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	16 April 2002	Braccini, R

CATEGORY OF CITED DOCUMENTS

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& : member of the same patent family, corresponding document

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The members are as contained in the European Patent Office EDP file on
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16-04-2002

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			JP	11168838	A	22-06-1999
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			EP	1043824	A2	11-10-2000
JP 10051968	A	20-02-1998	NONE			

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